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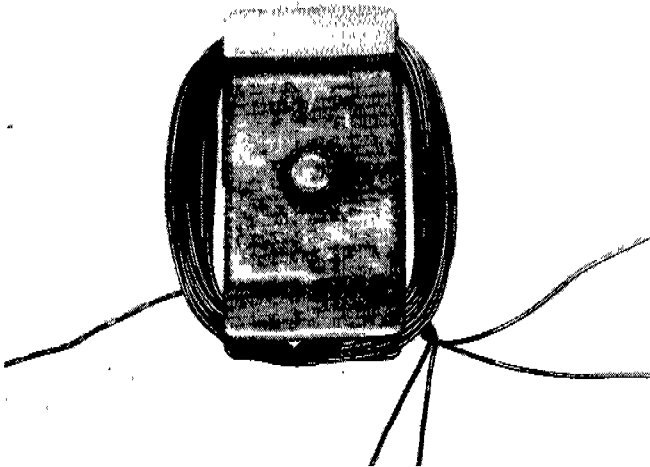
THERMAL OVERLOAD TESTING OF HERMETIC MAGNET WIRE

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INTRODUCTION

Burnout or overload testing fits into the abnormal operation portion of magnet wire evaluations. Over the years, several methods have been used by various laboratories. NEMA has standardized on an overload test outlined in NEMA MW1000-73 section 53.1.1 (ANSI C9.100-1973). This test uses a twisted pair as a test sample and employs stepwise increasing current for heating. The time to burnout is used in a formula which gives a figure of merit to rank various materials.

The test to be discussed in this paper is different from the NEMA procedure. It is a rapid burnout test using a bifilar coilette as a sample. Constant current flows through the windings with a 115V stress voltage applied between them. Failure is detected by leakage between windings.

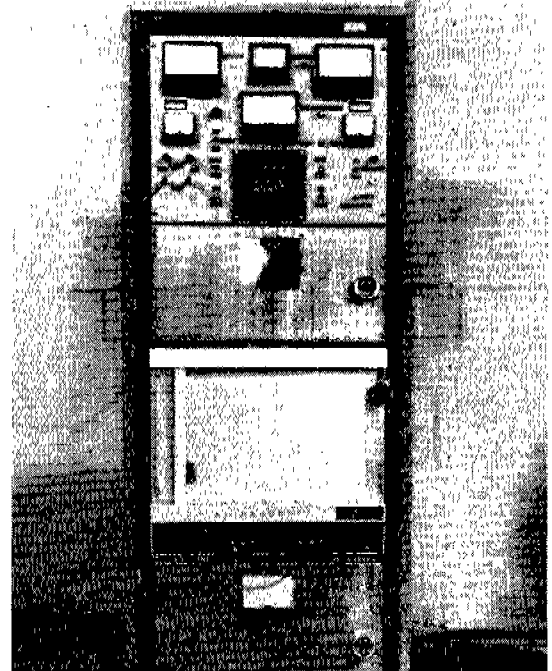


BIFILAR COILETTE

FIGURE NO. 1

TEST SPECIMEN

As mentioned before, the specimen employed is a bifilar coilette wound on a form in a random fashion. (See Figure 1). Both of the windings are wound simultaneously onto the form. After half the turns are in, the thermocouple is installed, after which the winding is completed. Various numbers of turns are used depending on the wire size involved. As an example: For No. 18 wire, 20 turns are used in each winding for a total of 40 turns. The ends of the magnet wire are stripped and fastened to the post of the tester. No leads or other connections are employed.



RAPID BURNOUT TESTER

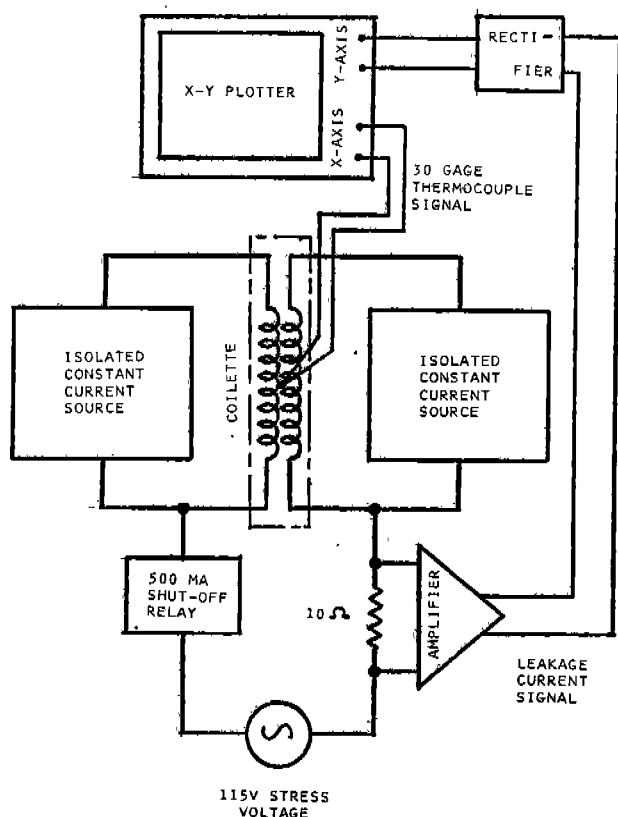
FIGURE NO. 2

APPARATUS AND PROCEDURE

The rapid burnout tester is shown in Figure 2 with the circuit described in schematic form in Figure 3. Each of the two windings of the coillette is heated by a variable controlled current source through isolation transformers.

A stress voltage of 115 volts AC is applied between the windings. The output of a 30 gauge chromel-alumel thermocouple is fed into the X-axis of an XY plotter. To sense the leakage the voltage drop across a 10 ohm resistor is amplified, rectified and fed into the plotter's Y-axis. When the current is turned on, recording of leakage versus temperature on the XY plotter progresses until 500 milliamp leakage current flows between the windings, at which time the test shuts off and the time is recorded. During the test the coillette is contained in a semi-sealed compartment with no air flow. As soon as the test is completed a blower exhausts this chamber.

A typical leakage versus temperature plot is shown in Figure 4. This curve has three important points. The first is the leakage inception point, which is loosely defined as the point where the curve leaves



MAGNET WIRE BURNOUT TESTER

FIGURE NO. 3

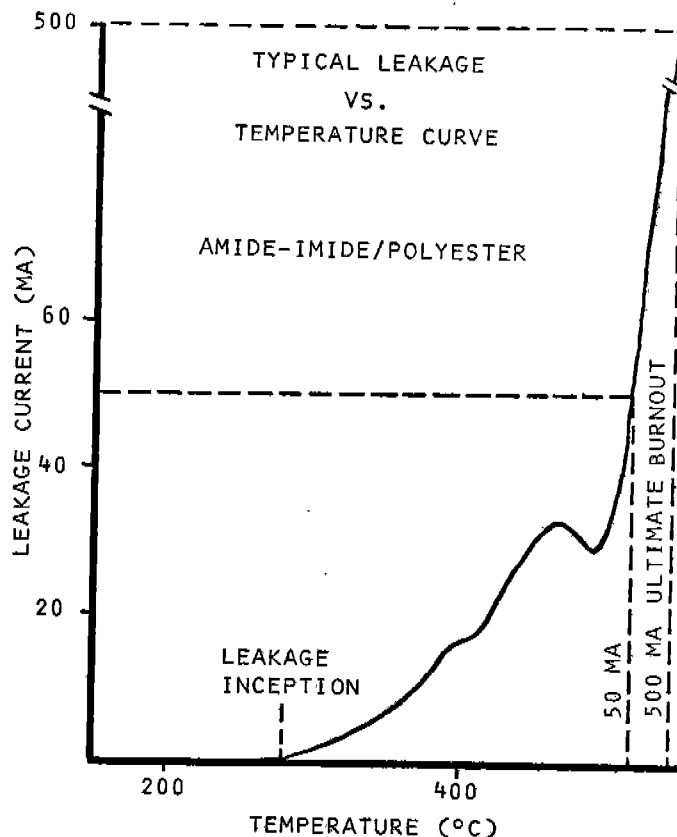


FIGURE NO. 4

the X-axis. This is simply the temperature at which measurable leakage occurs. As further work progresses, it is expected that this point will be defined either by a specific amount of leakage current, or by some angle intercept with the X-axis. At the present, it is an estimated figure used for evaluation purposes only. The second point of interest is the temperature at 50 milliamps leakage. This is a value widely used in specifications for magnet wire. The third point is the temperature at the cutoff point of 500 milliamps leakage. In all but a few cases this represents the ultimate burnout temperature of the material. A few enamels will reach extremely conductive states at this temperature without true burnout occurring, however these are the exceptions.

EFFECT OF HEATING RATE

Differences in wire size are taken care of by changing the heating current so that the rate of temperature rise is kept essentially constant. Different currents are also used when aluminum wire is being tested.

Figure 5 shows typical rate of rise curves at various heating currents using No. 18 wire. For this size wire the standard test procedure calls for 40 amps. Lower currents were run to give an indication of the effect of very long test cycles on the test results obtained. This was an attempt to predict whether the test would roughly correlate with the NEMA overload test which is run at slower

heating rates over a longer time.

Figure 6 represents the leakage versus temperature plots at these various heating rates. It can be seen from this plot that the ultimate burnout temperature is relatively unaffected by heating rate until the rate becomes extremely slow. At this point the burnout temperature is reduced significantly indicating that cure and degradation are taking place at lower temperatures.

EFFECT OF TESTING ENVIRONMENT AND CONDITIONING

The rest of this paper contains typical results obtained from the rapid burnout test. These are presented as examples only since not enough data points were run in each case to give statistical significance in ranking materials or differentiating between test conditions.

Tests of amide-imide overcoated polyester under various conditions is shown in Figure 7. Three of the curves represent tests run on unconditioned samples; first in air, then in R-12 and finally in R-22. These tests showed that the test conditions did not have a drastic effect on the ultimate burnout temperatures of the films, although the shape of the curve was affected. Later tests following refrigerant soak were run only in air to save time. On the same figure are curves for the same magnet wire film tested in air following either a one week exposure to liquid R-12 or to liquid R-22. These runs indicated that no drastic effect was obtained by refrigerant soak. The one week soak time was chosen after testing indicated that the film is essentially saturated with refrigerant after four days in liquid. Later work will have to show whether longer soak times have any effect and what these effects mean.

COMPARATIVE PERFORMANCE OF COMMON HERMETIC MAGNET WIRE FILMS

The remaining graphs show typical performance data

for several films either currently or previously used in the Hermetic Industry. Lecton® was a modified acrylic used some time ago, primarily in R-12 systems. Urethane modified polyvinyl formal or Formvar Urethane was widely used in both R-12 and R-22 systems until approximately 1969. Amide-imide over theic polyester and single component polyester-imide films are the two major materials in use today. Amide-imide and polyimide are used primarily in large R-22 systems where extreme overload resistance is required. Figure 8 shows the relative performance of all these materials tested in air without any sample conditioning. It can be seen from this curve that each material exhibits a characteristic shape in its plot, as well as a characteristic burnout temperature. This shape appears to be peculiar to the material, but can be affected by degree of cure, modifiers, etc. In Figure 9 is seen a comparison of the same magnet wire films after a one week soak in liquid R-12. The test was performed in air. In general, the same ranking of materials exists after the refrigerant soak with some minor changes. In Figure 10 is seen a comparison after one week in liquid R-22. These results are quite similar to the results in R-12 with the exception that the amide-imide material became quite lossy at lower temperatures. A re-test using a higher cutoff point showed that ultimate burnout occurred at about the same temperature as in the other runs. It is not known why the leakage was affected in this way.

SUMMARY

The rapid burnout test provides a quick and inexpensive way to rate the overload resistance of hermetic magnet wire films. It gives good correlation with known field experience with various enamels and has been used for many years as a specification test for magnet wire. While not presented as a replacement for the NEMA overload test it provides an alternate technique by which additional information can be obtained.

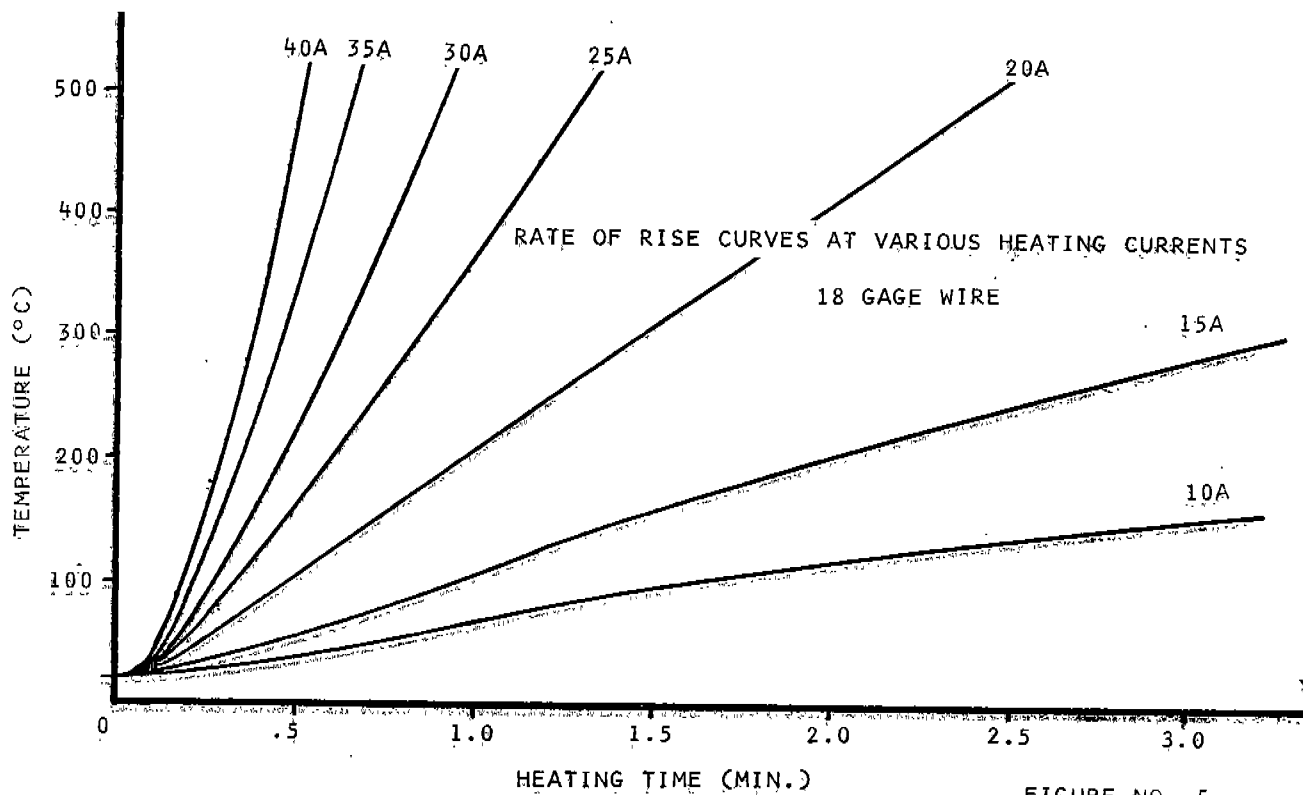


FIGURE NO. 5

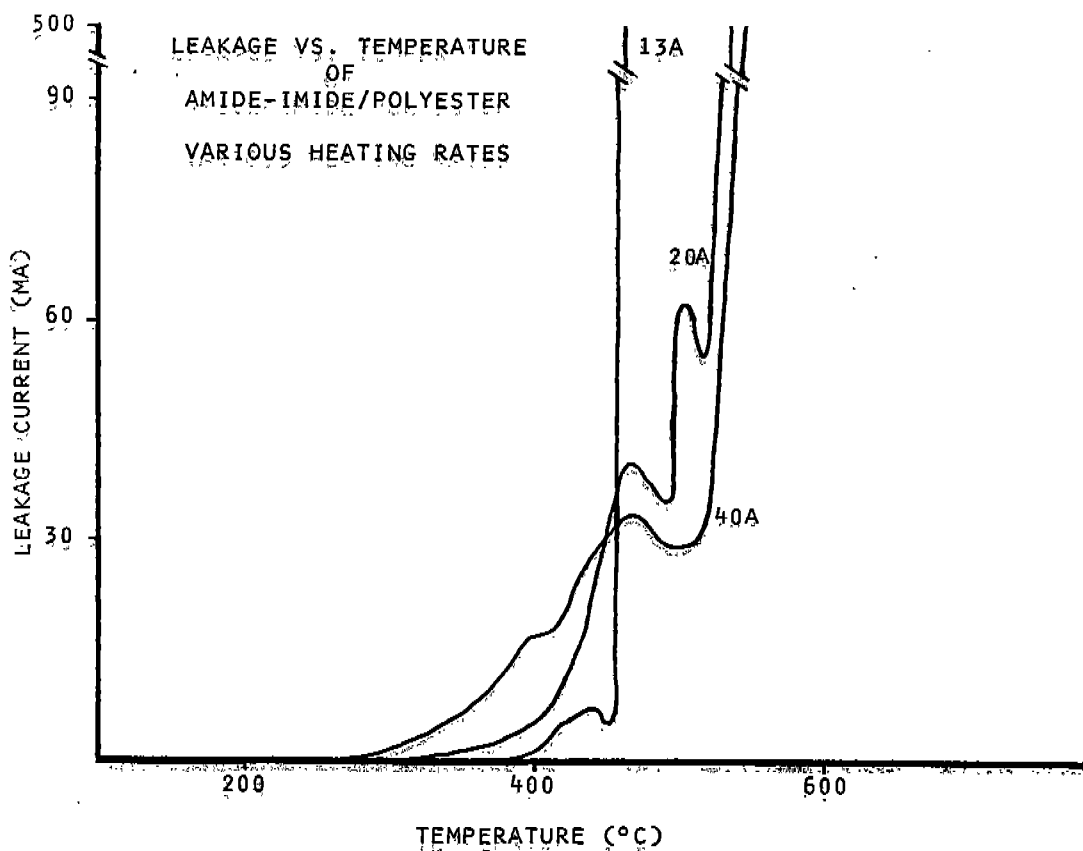


FIGURE NO. 6

LEAKAGE VS. TEMPERATURE; COMPARISON OF ALL MATERIALS
AFTER 1 WEEK SOAK IN R12 (250 PSI, 68°C), TESTED IN AIR

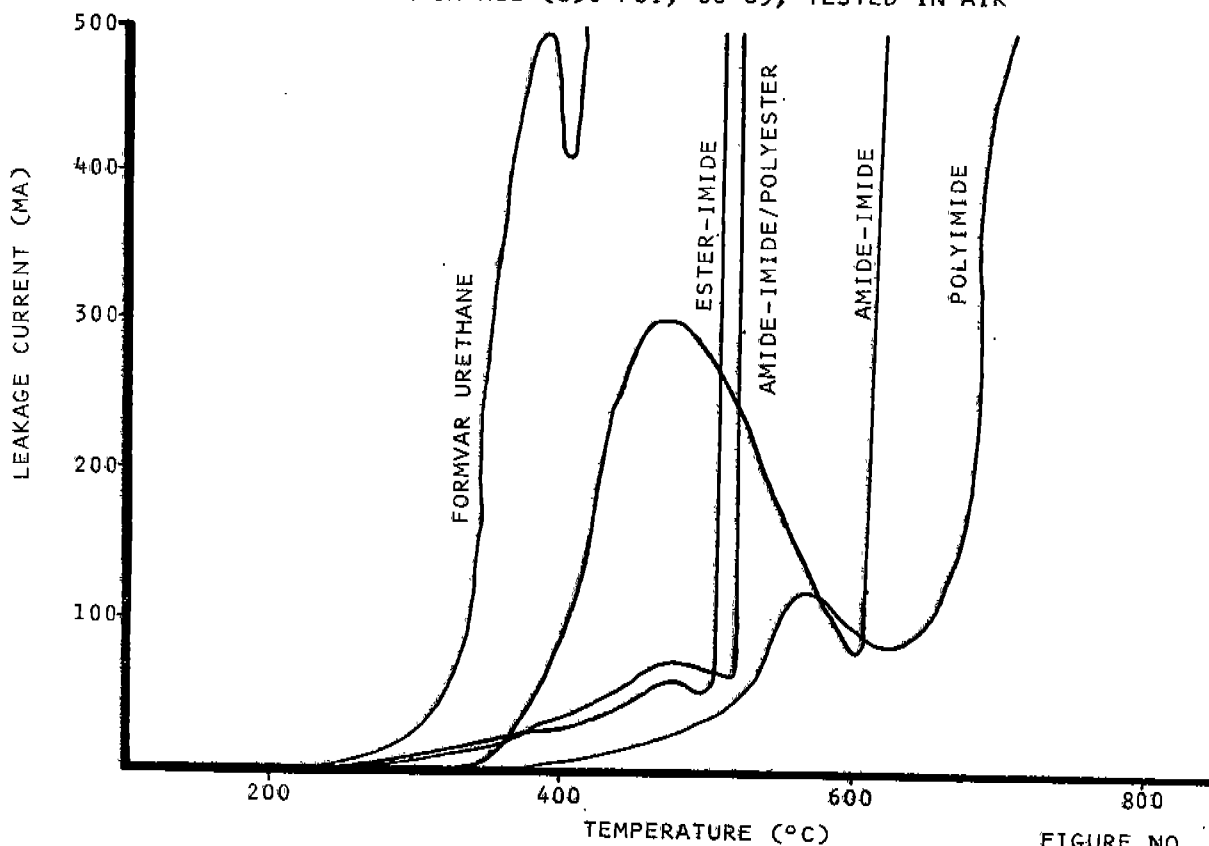


FIGURE NO. 9

LEAKAGE VS. TEMPERATURE; COMPARISON OF ALL MATERIALS
AFTER 1 WEEK SOAK IN R22 (410 PSI, 68°C); TESTED IN AIR

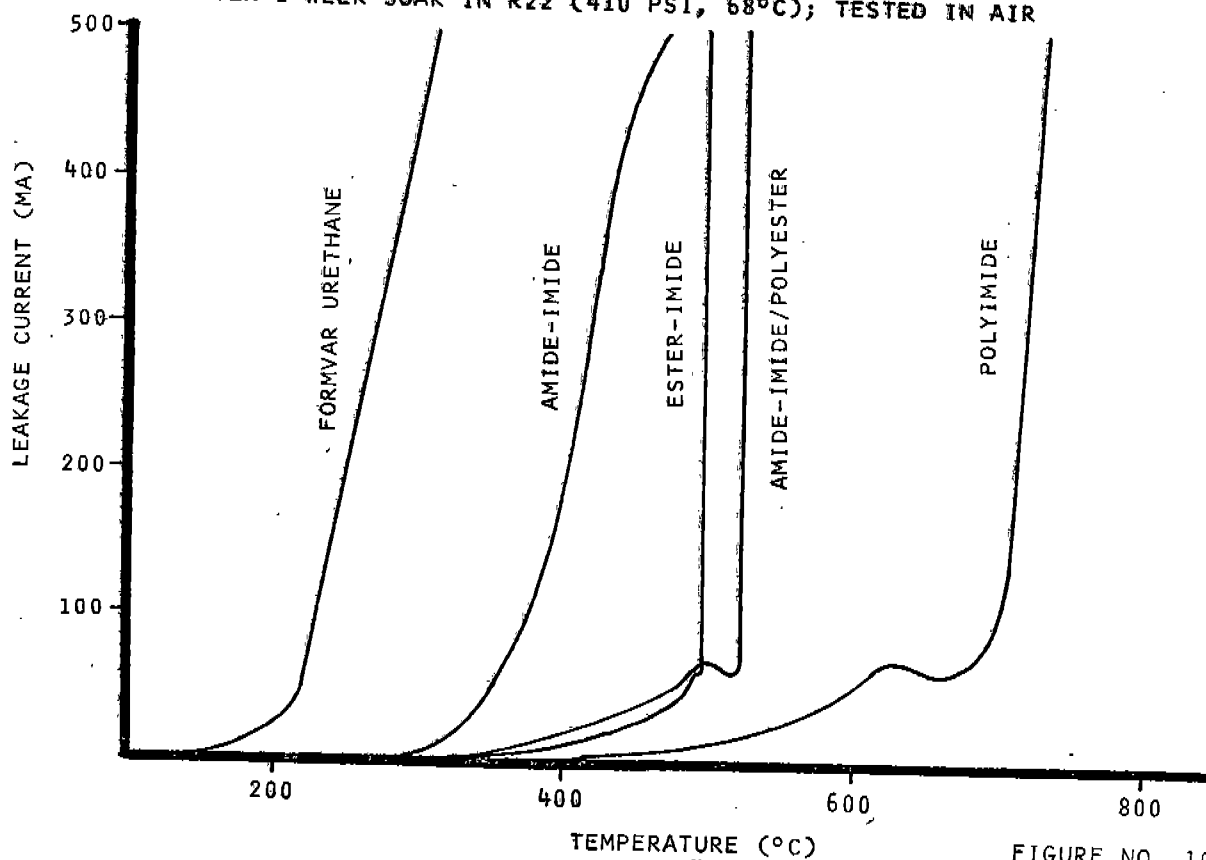


FIGURE NO. 10

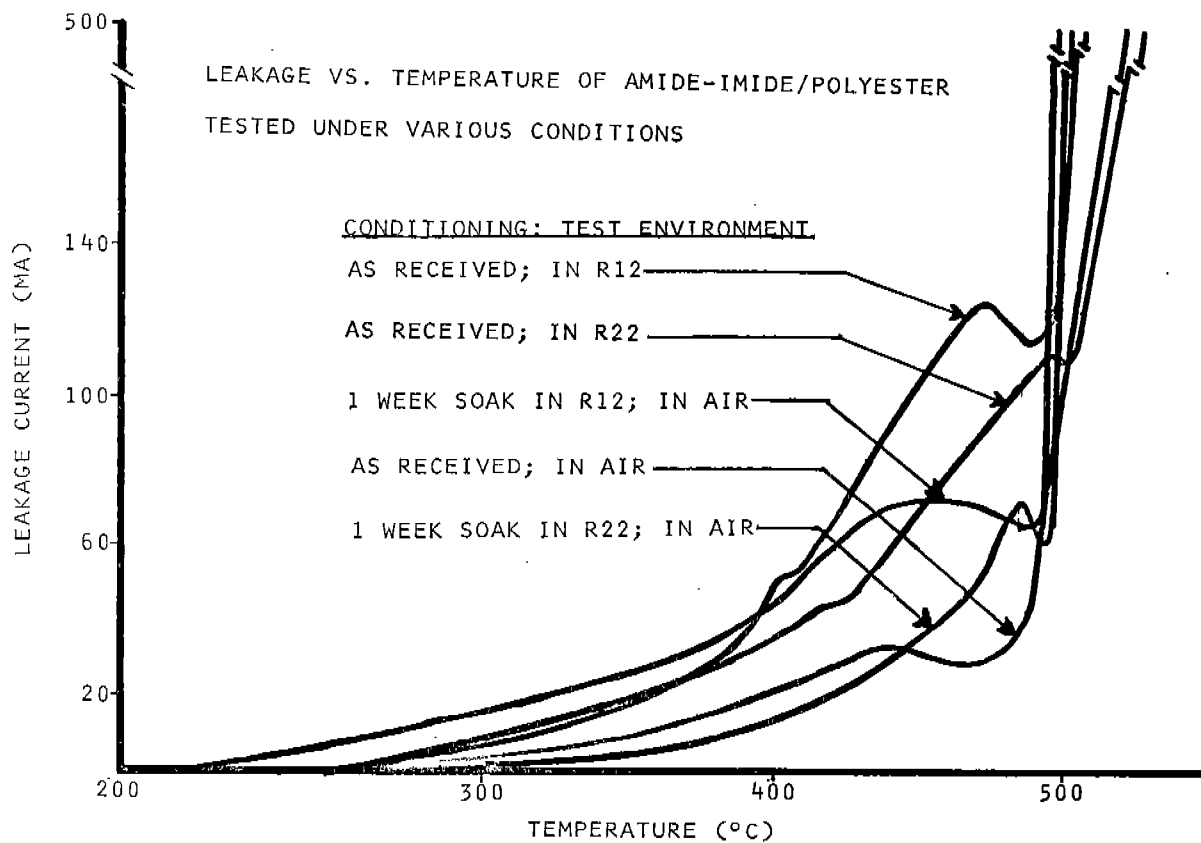


FIGURE NO. 7

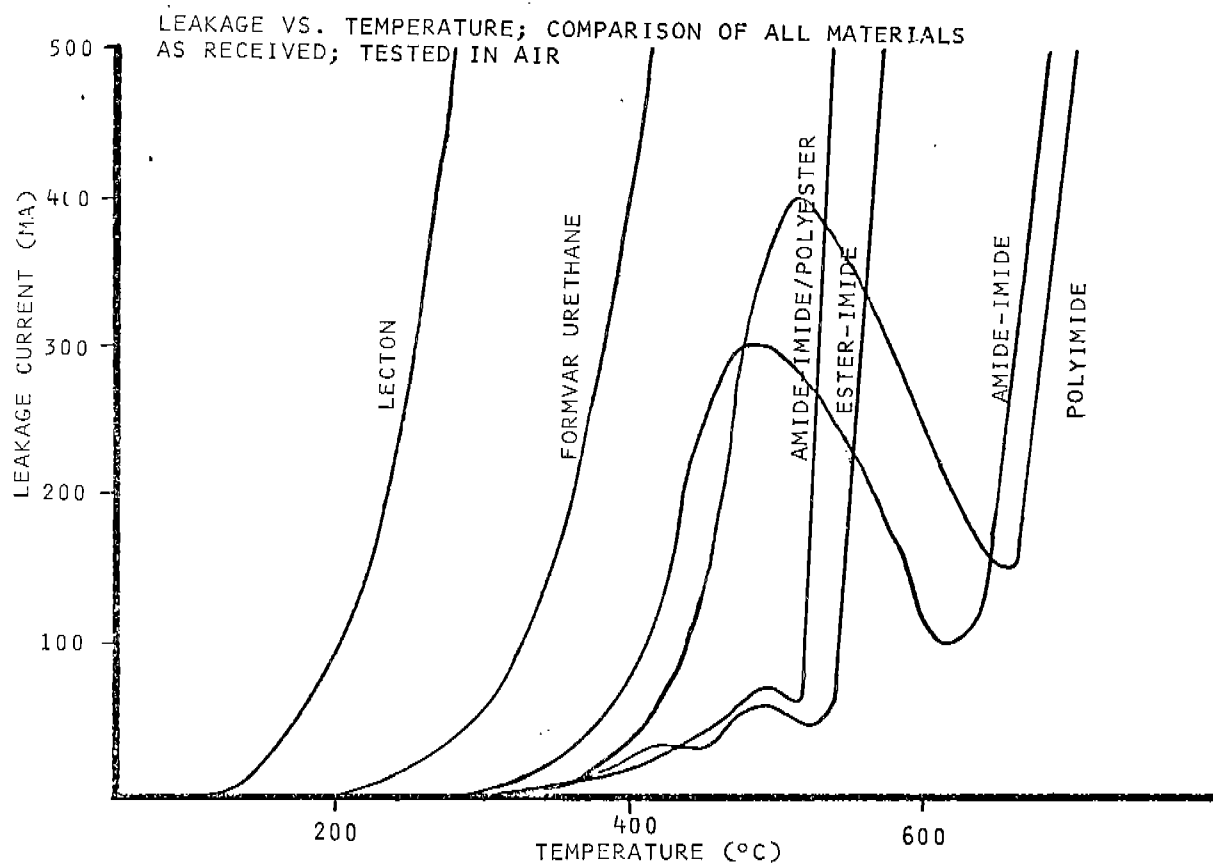


FIGURE NO. 8